Environment Canada
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A REPORT ON
1989 WATER LEVELS
OF THE GREAT LAKES

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January 1990

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1.0 PURPOSE AND SCOPE

This report summarizes the events that took place in 1989 relative to water levels on the Great Lakes - St. Lawrence River. The report begins by examining the hydrologic factors that have shaped the water levels on the Great Lakes in 1989. It then briefly describes some of the effects of the 1989 levels. The report also contains a summary of the operations related to Lake Superior and Lake Ontario regulation, and discusses a few of the initiatives taken by the federal government to address the water levels issue.

The format of this report is similar to that of previous annual reports prepared for 1985-1988, but with some additional information. First, a short section has been added to help familiarize readers with the physical features and hydrology of the Great Lakes - St. Lawrence River System. Because record high lake levels occurred in 1985 and 1986, the reports for these years concentrated on the factors causing these high levels, how they compared with previous high records, and the damages high lake levels and storms have caused. With the rapid drop in lake levels in late 1986 and 1987, and sometimes below-average water level conditions in 1989, it is useful to explain the cause of this turn-around; and how 1989 levels compare with the long-term average and minimum levels. Additional data such as flows in the St. Clair and Detroit River System, as well as a brief discussion on the operations of all the major Great Lakes diversions are included in this report for the first time. A discussion on the water levels at Montreal Harbour has been added, as well as a section on the Great Lakes Water Levels Reference Study.

All data are in metric units. Lake water level elevations are in metres on the International Great Lakes Datum (1955), which has reference zero elevation at mean sea level at Pointe-au-Pere in the Gulf of St. Lawrence. The preliminary data used in this report (for example, precipitation and flows) may be subject to revisions by the agencies issuing these data.

2.0 PHYSICAL FEATURES OF THE GREAT LAKES - ST. LAWRENCE RIVER BASIN

A detailed description of the hydrology of the Great Lakes - St. Lawrence River Basin can be found in several recent reports, including one entitled: "Living With The Lakes: Challenges and Opportunities" prepared by the International Joint Commission's Project Management Team dated May 1989. The following is a summary based on these reports.

The Great Lakes Basin is about 770 000 square kilometres in area (see Figure 1). The basin extends from about 80 kilometres west of the western tip of Lake Superior to the outlet of Lake Ontario, and from Lake Nipigon in the Province of Ontario south to the central portion of Ohio. About 319 000 square kilometres are in Canada and the remaining 451 000 square kilometres are in the

United States and include the entire State of Michigan and portions of Minnesota, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania and New York. The Great Lakes with their connecting channels and Lake St. Clair have a total water surface area of about 246 000 square kilometres. The St. Lawrence River, from Lake Ontario to Quebec City, adds an additional 337 000 square kilometres of drainage area, most of which is located in the Province of Quebec and the State of New York. The dimensions of the Great Lakes and other physical dimensions are shown in Table 1.

As shown in Figure 2, the Great Lakes comprise a series of natural storage reservoirs which discharge into the St. Lawrence River. They are positioned in a step-wise manner, with Lake Superior being the highest and Lake Ontario the lowest, and are interconnected by a series of rivers and straits. Lake Superior discharges through the St. Marys River into Lake Huron. Lake Michigan also flows into Lake Huron through the Straits of Mackinac. The hydraulically unified Lakes Michigan and Huron (often called Lakes Michigan-Huron) discharge into Lake Erie through the St. Clair River - Lake St. Clair - Detroit River system. Lake Erie's outflow is discharged through the Niagara River into Lake Ontario, and Lake Ontario in turn, flows into the Gulf of St. Lawrence, then the Atlantic Ocean, via the St. Lawrence River.

Water levels of the Great Lakes fluctuate according to the climate of the region. Over-lake precipitation, evaporation and runoff in the basin are the main factors affecting water level fluctuations. Other natural factors also having an effect on lake levels are flow retardations due to ice in the river in the winter, or due to aquatic growth in the summer, and meteorological disturbances. Artificial factors include dredging, diversions, consumptive uses, and regulation. A detailed description of these factors can be found in the report by the International Great Lakes Levels Board dated 1973.

3.0 FACTORS AFFECTING THE GREAT LAKES LEVELS IN 1989

3.1 Hydrologic Conditions Leading to 1989

In 1985, a new high precipitation record of 1017 millimetres was set, exceeding the long-term basin-wide average of 812 mm by 25 percent. This event, following 18 years of generally above-average precipitation, led to the occurrence of record high water levels on all the Great Lakes except Lake Ontario, a condition which continued through 1986 and into early 1987. Very high outflows from Lake Ontario under regulation made that the only lake to escape setting record high levels during that time, although levels were well above average.

During 1987 and 1988, the lakes experienced an unprecedented rapid drop in levels that began in late 1986. The rate of this drop surpassed that of the previous 20th century extreme event of 1930-

31. Precipitation was low from late fall of 1986 to June 1987, and again in the spring of 1988. Also, low runoff and high evaporation in the basin were experienced in early 1987 and again in early 1988. As a result, severe drought conditions occurred throughout much of the Great Lakes Basin in 1987 and particularly 1988. By mid-1988, lake levels had fallen to 20th century average levels. Lake Superior, however, was below average for much of 1988.

Water levels at Montreal Harbour were near average for 1986 and early 1987. However, low local runoff and decreasing St. Lawrence River flows in the second half of 1987 and much of 1988 have caused the levels there to drop to much below average, including new record lows for seven months in 1988.

The water levels of the Great Lakes at the beginning of 1989 were at or very near their long-term averages for that time of the year. Next, they followed the usual seasonal cycle in which water level rises in the spring and summer months due to increased runoff from snow melt. Lake levels then dropped in the late summer and fall months due to reduced runoff and increased evaporation. The Great Lakes basin-wide precipitation for 1989 was slightly below average. This combined with the reduced runoff and high evaporation to cause a further but slight drop in lake levels by the end of 1989.

The next several sections discuss briefly each of the factors in the Great Lakes hydrological cycle.

3.2 Precipitation

Records since 1900 show that about 812 mm of precipitation falls on the Great Lakes Basin each year. Average annual precipitation varies from lake basin to lake basin, and it ranges from less than 700 mm northwest of Lake Superior to as much as 1320 mm in the Adirondacks east of Lake Ontario in New York State.

Table 2 compares the monthly precipitation for each lake basin in 1988 and 1989 with the long-term averages. Overall, precipitation on the Great Lakes Basin in 1989 was 92% of average, with no exceptional or unusual events set in the year. Below average precipitation on the upper lakes is expected to have some impacts on the downstream lakes over the next year or two.

On the Lake Superior basin, precipitation in 1989 has been about 88% of average, with July and subsequent fall months much drier than usual. Precipitation on the Lakes Michigan-Huron basin was 89% of average. The dry July-October months were followed by above-average precipitation in November and below average in December. As these upper Great Lakes account for over 80% of the water supplies to the lower Great Lakes, conditions on the upper lakes are dominant factors in determining future water level conditions on the lower lakes.

The Lake Erie basin had below average precipitation for four consecutive months in early 1989, followed by well above average precipitation in May, June, and again in September and November. The Lake Erie basin received average precipitation in 1989. The precipitation pattern on the Lake Ontario basin is similar to that of Lake Erie, with low precipitation in early 1989, high precipitation in May and June and again towards the end of the year. The precipitation on Lake Ontario basin was also near average.

3.3 Runoff

Preliminary streamflow data from a number of Canadian tributaries draining into the Great Lakes are summarized in Table 3. These tributaries were selected as being representative of the total runoff to the Great Lakes from Canada. Final official data for all Canadian gauged streams can be found in annual Surface Water Data reports published by Water Resources Branch of Environment Canada. United States streamflow data are published by the U.S. Geological Survey in its annual water supply papers. As data from the selected Canadian tributaries were available at the writing of this report, they have been used in the assessment.

As shown in Table 3, above average runoff occurred in the Canadian portion of the Lake Superior basin throughout much of 1989 despite the fact that the precipitation on the Lake Superior basin (on both Canadian and U.S. portions), was slightly below average for the same year. In order to explain this apparent inconsistency, it is necessary to examine the precipitation in the previous year (1988) and the physiography of the area.

A closer look at Table 2 shows that precipitation on the Lake Superior basin was very high in the last five months of 1988 and again in January 1989. The vast land portion of the Lake Superior basin with its numerous small lakes, swamps and tributaries act as temporary storage for the precipitation that falls on the basin. Precipitation in the form of snow on the upper lakes also has less chance of melting in the winter. Thus, although it occurred in 1988, the high precipitation had a prolonged impact on the runoff to Lake Superior through the first half of 1989.

Similar to Lake Superior, runoff in the Lake Huron basin was high in the latter part of 1988 and in the first two months in 1989, due also to above-average precipitation in the second half of 1988. Subsequent below-average precipitation in the remainder of 1989 caused the runoff to decline to below average values except June. June was the only month with above average runoff throughout the Great Lakes Basin, due to high precipitation in May and June.

Due to the absence of swamps, small lakes and rivers that act as temporary storage and human activities such as urbanization and draining and irrigation, runoff in the lower lakes is more

sensitive to the change in precipitation. The high precipitation in May and June 1989 caused an increased runoff to Lake Erie in June. Low precipitation in the rest of the year caused low runoff.

High precipitation on the Lake Ontario basin in May and June caused high runoff to that lake also in these two months. Runoff to Lake Ontario the rest of the year ranged from below average in the late summer to well above average in November.

Runoff in the Canadian basin for 1989 was slightly below average.

3.4 Evaporation

Evaporation occurs from both land and water surfaces of the Great Lakes basin. Only lake surface evaporation is discussed in this report as evaporation and transpiration (from vegetation) from land is reflected in the runoff characteristics.

There is no direct means of measuring over-lake evaporation. Several estimates using energy balance, water balance and empirical mass transfer relationships have been made in the past by lake researchers. These estimates vary, and only those determined by the Atmospheric Environment Service are used in Table 4.

In general, evaporation is least in the spring when the lakes are cold relative to the air above them and is greatest in the fall and early winter when the lakes are warm relative to the air above them. On the upper Great Lakes, condensation sometimes occurs and the values can be negative as shown in Table 4.

In 1988, evaporation was higher than average on all the lakes except Lake Ontario. This was one of the contributing factors to the continuing decline in lake levels. Based on preliminary data through November, evaporation in 1989 was near average on all the Great Lakes.

New monthly record high values were observed for February 1989 on Lakes Superior, Huron and Georgian Bay when compared with the records since 1965.

3.5 Outflows

Table 5 lists the monthly outflows for the upper lakes for 1988 and 1989. The outflow from Lake Superior in 1988 was 1840 cms, or 86% of average. This was due to much lower than average water level conditions on the lake for much of 1988. Increased supplies in early 1989 helped to raise the lake levels and thus increased its outflows. However, reductions in supplies and lake levels towards the end of 1989 also caused the outflows to drop. Outflow from Lake Superior for 1989 was slightly above average.

The outflow from Lakes Michigan-Huron in 1988 was 5410 cms, or 104%

of average. This was due to higher than average water level conditions on these lakes in the first half of 1988. A return to near average lake level conditions for the rest of the year also caused the outflows to be near average. For 1989, the outflow from Lakes Michigan-Huron was near average since levels on these lakes were close to average for much of the year.

The outflow from Lake Erie in 1989 was about 6040 cms, or 104% of average. This was due to higher than average water level conditions on the lake for much of the year. The outflow of Lake Ontario for 1989 was about 6880 cms which was near average.

3.6 Other Factors

It is worthwhile to mention the operations of the major diversions including the Long Lac, Ogoki, Chicago, Welland and the New York State Barge Canal diversions. These diversions occasionally are the subject of controversy, especially at times of extreme high or low lake level conditions.

The Long Lac and Ogoki Diversion projects divert a part of the James Bay water into the Lake Superior basin. These diversions began in 1939 and 1943, respectively. The average rate of diversion is 159 cms. In 1988, the combined Long Lac and Ogoki rate of diversion was near average at about 161 cms. Preliminary figures show that the rate of diversion for 1989 will also be near average.

The Chicago diversion takes water from Lake Michigan for the purpose of navigation, domestic and sanitary uses, and hydro-electric power generation in the Illinois Waterway. The water diverted is discharged into the upper Mississippi River. The 1967 decree by the U.S. Supreme Court specifies a maximum allowable diversion at 91 cms. A 1980 Court amendment permits the use of a 40-year period in calculating the running average diversion. In 1988, the diversion was about 81 cms. Preliminary figures for 1989 show that the rate of diversion will be near or slightly above the 91 cms figure.

The Welland Canal diversion in 1988 was 239 cms, or 107% of average for the period 1950-1987. Record high diversions were recorded in January and February of 1988. In 1989, the diversion was about 243 cms, or 109% of average.

The New York State Barge Canal diverts water for navigation from the Niagara River At Tonawanda, New York. All of the water diverted is eventually returned to Lake Ontario. In 1988, the diversion was 14 cms and in 1989 the diversion was about 13 cms.

3.7 Lake Water Levels

Table 6 shows a comparison of 1988 and 1989 water levels with previous records (average, maximum and minimum) for the Great Lakes

and for Montreal Harbour. These are also shown graphically in Figures 3 to 8. Overall water levels have changed very little from those of 1988. Levels on most of the lakes remain fairly close to their long term averages.

Water levels on Lake Superior were near average in the first half of 1989. Below average precipitation for much of 1989 caused the lake levels to drop to below average towards the end of the year. Levels on Lakes Michigan-Huron were near average for much of 1989 until near the end of the year at which time they were about 0.2 metre below average. Levels on Lake St. Clair were generally 0.2 metre below average in 1989, due to a combination of low precipitation on its basin, and slightly below average inflows from Lakes Michigan Huron.

Lake Erie's water level was at or slightly above average in early 1989. Very high precipitation in May and June caused the lake levels to rise rapidly in these months. Lake levels began their usual decline during the rest of the year, although lake levels did rise somewhat in November due to high precipitation on the Lake Eire basin. By year-end, the level on Lake Erie was slightly below average.

Lake Ontario's water level was about 0.2 metre below average in the first five months of 1989. It rose to above average in June and July due to the high precipitation on its basin and high inflows from Lake Erie. Levels then followed their normal fall decline and, by the end of 1989, were slightly above average.

Water levels at Montreal Harbour were much below average for much of 1988 and 1989. New record minimums were set in the first four months in 1989 and again in October. Very high flows in November caused the levels to rise sharply to near average. By year-end, levels have improved to about 0.2 metre above average.

4.0 EFFECTS OF GREAT LAKES WATER LEVELS

4.1 General

With the water levels of 1989 being fairly close to long term average on all of the lakes there has been considerably less concern over the danger of flooding and erosion damage. No significant damage was reported during the year along the Canadian Great Lakes - St. Lawrence shoreline despite a number of high wind warnings issued by the Atmospheric Environment Service.

4.2 Nature and Extent of Impacts

Some boaters and a few property owners have raised concerns over what appears to be low water levels. However, levels are in fact quite close to their long term average. These reactions appear to be due to the drastic drop in levels from record high levels in

1986 to near average levels in 1988 and 1989. Despite the occasional concern from boaters and marina operators over reappearing rocks and higher dredging costs, no major damage has been reported. A drop in the number of inquiries concerning problems associated with low levels has been noticed since the summer of 1988 perhaps as people become more accustomed to the current average levels. A slight increase in water levels on Lakes Erie and Ontario and the upper St. Lawrence River during the recreational boating season may have contributed to this decrease in the number of enquiries.

Wider beaches from those of previous years made areas such as Wasaga, Saugeen, Grand Bend and Long Point popular summer spots this year.

4.3 Storm Events

A number of small storms passed over the Great Lakes - St. Lawrence River Basin during the year. As is the norm, the worst of these occurred in the late fall. Significant events are listed below.

October 5, 1989 - Strong winds from the north-east created waves 2-3 metres in height on Lake Ontario and Lake Erie.

October 14, 1989 - Barometric pressure variations associated with a thunderstorm created rapid fluctuations in some harbours along the north-eastern Lake Ontario shoreline.

November 20, 1989 - Strong north-west winds, in excess of 40 knots km/hr, created a surge at the Goderich gauge of 70cm., the highest recorded in over 30 years.

There were no reports of significant damage due to any of the above events.

5.0 WATER MANAGEMENT ACTIONS TAKEN RELATED TO GREAT LAKES WATER LEVELS

5.1 Lake Superior Regulation

Table 7 lists the Lake Superior and Lakes Michigan-Huron net basin supplies for 1988 and 1989, and their comparison with the long-term averages. Net basin supply is a measure, expressed in cms-months, of the net water input to the Great Lakes resulting from precipitation, evaporation and runoff. For Lake Superior, the supplies for 1988 was 23190 cms-months which was slightly below average. This slight difference from average was equivalent to a reduction of 0.05 metre storage of water on the lake by the end of 1988. Preliminary figures show that the supplies to Lake Superior

for 1989 would also be below average.

The supplies to Lakes Michigan-Huron in 1988 were only 82 percent of average. Compared to the long-term annual supply, this translates to a reduction of 0.15 metre storage of water on the lakes by year-end. Supplies for 1989 have been below average.

There were no unusual hydrologic conditions in 1988 or 1989 that prompted any departures from the Lake Superior's regulation plan - Plan 1977.

5.2 Lake Ontario Regulation

In 1988, actual monthly outflows from Lake Ontario were very close to those specified by Plan 1958-D, as well as near average. Record low water level conditions were experienced at Montreal Harbour for seven months in that year, due primarily to very low local runoff in that part of the watershed area. With Lake Ontario levels expected to continue falling below average in early 1989, the St. Lawrence River Board reduced the lake's outflows beginning in late March. Unexpected high precipitation in May and June (see Table 2) combined with the reduced outflow to raise the lake level rapidly. By late 1989, levels on Lake Ontario returned to near average conditions, and the outflow for the year was the same as the long-term average.

5.3 Great Lakes Water Level Communications Centre (GLWLCC)

The Great Lakes Water Level Communications Centre in Burlington, Ontario, continued it's activities in 1989 by issuing the monthly news release, providing information and responses to inquiries from the public and media, and by participating in meetings around the Great Lakes. The Centre also provided support for the International Joint Commission Water Levels Reference Study.

The GLWLCC responded to approximately 300 telephone and mail requests for information. These requests included queries over seemingly low levels, requests for water level data, requests for documentation, and inquiries regarding the International Joint Commission Water Levels Study. A few inquiries were also made regarding rapid rises and/or falls in levels on particularly windy/stormy days.

5.4 International Joint Commission Water Levels Reference Study

1989 saw the completion of the Project Management Team's Phase I report on the Water Levels Reference Study as initiated in 1986. An interim report was previously released in October 1988. The Phase I report and seven annexes were presented to the IJC Commissioners in September of 1989. Public comment on the reports took place at the IJC Biennial Meeting, held in Hamilton, on the 14th of October.

6.0 FORECAST OF FUTURE WATER LEVEL CONDITIONS

A six-month forecast of the water levels of the Great Lakes and Montreal Harbour is shown in Figures 3-8. It should be noted that the water levels of the Great Lakes fluctuate according to the climatic conditions in the Great Lakes Basin. Since it is not possible to forecast accurately and in the long-term the climate, the forecasts are made assuming average, wet and dry climatic conditions for the next six months.

Under average climatic conditions, the upper lakes and Lake St. Clair will remain generally 0.2 metre below average, whereas Lakes Erie and Ontario will remain near average and slightly below average, respectively.

7.0 FINDINGS AND CONCLUSIONS

1. There was generally a continuing though very slight drop in the water levels of the Great Lakes during 1989. This was caused by a combination of below average precipitation and runoff. There were no extreme hydrological events in 1989 which is considered an average year in terms of lake levels and outflows.

2. The below-average precipitation on the upper lakes basins in 1989 is expected to have some impact on the lower lakes over the next two years in terms of reduced water supplies to these lakes.

3. No discretionary actions were required in the regulation of the outflows of Lake Superior, due to the lack of any extreme hydrologic conditions on either Lake Superior or Lakes Michigan-Huron. There were some outflow reductions in early 1989 in response to falling Lake Ontario levels. Improved climatic conditions later on enabled a return to the plan flows.

4. With lake levels near their long-term averages and the absence of severe storms in 1989, there have been no reports of flood and erosion damages. There were some reports of problems experienced by boaters over average or below average water level conditions. However, no major damage has been reported.

6. A slight increase in water levels on Lakes Erie, Ontario and the upper St. Lawrence River (compared to 1988 and earlier) during the recreational boating season might have contributed to the decrease in the number of inquiries and complaints.

7. Record low water level conditions occurred for seven months in 1988 and again for five months in 1989 at Montreal Harbour. These occurred when the outflows from Lake Ontario were near average and close to the flows specified by the regulation plan. This would suggest that perhaps Plan 1958-D could be examined with a view to giving more consideration to the water level conditions downstream when determining the lake's outflow.

Table 1 Dimensions of the Great Lakes

	Area	Volume	Shoreline Length		Water Depth	
			Mainland	Island	Average	Maximum
	Sq Km	Cu Km	Km	Km	Metres	Metres
Lake Superior	82100	12100	2780	1600	147	405
St. Mary's River	230		153	244		
Lake Michigan	57800	4920	2250	383	85	281
Lake Huron	59600	3540	2970	3180	59	229
St. Clair River	55		93	8		
Lake St. Clair	1110		210	204		6
Detroit River	100		96	116		
Lake Erie	25700	484	1290	116	19	64
Niagara River	60		111	60		
Lake Ontario	18960	1640	1020	125	87	244
St. Lawrence River*	610		484	567		

Source: Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data

* Measured from Lake Ontario to Cornwall/Massena.

Table 2 Precipitation on the Great Lakes Basin in 1988, 1989 and Their Comparison with Long-Term Average (millimetres)

Superior Basin

	Average	1988	% of Average	1989	% of Average
Jan	46.99	46.99	100	57.40	122
Feb	36.07	33.02	92	29.72	82
Mar	44.20	57.15	129	43.18	98
Apr	49.53	24.64	50	34.80	70
May	68.58	58.17	85	70.87	103
Jun	84.07	63.75	76	98.30	117
Jul	81.79	67.82	83	36.32	44
Aug	82.04	172.21	210	81.03*	99*
Sep	89.41	88.14	99	54.10*	61*
Oct	67.56	80.77	120	55.63*	82*
Nov	62.99	100.08	159	56.64*	90*
Dec.	49.02	59.44	121	56.13*	114*
Total	762.25	852.17	112	674.12*	88*

Michigan-Huron Basin

	Average	1988	% of Average	1989	% of Average
Jan	51.82	55.12	106	45.72	88
Feb	43.43	47.75	110	31.24	72
Mar	54.61	54.86	100	63.50	116
Apr	64.01	72.14	113	38.10	60
May	75.18	35.05	47	91.95	122
Jun	78.49	28.45	36	87.88	112
Jul	74.42	71.37	96	40.13*	54*
Aug	77.98	112.01	144	72.39*	93*
Sep	87.12	93.98	108	52.58*	60*
Oct	70.36	120.14	171	67.56*	96*
Nov	68.58	126.49	184	88.39*	129*
Dec	58.42	57.40	98	38.86*	67*
Total	804.92	874.76	109	718.10*	89*

Erie Basin

	Average	1988	% of Average	1989	% of Average
Jan	60.96	32.26	53	46.23	76
Feb	52.07	58.93	113	30.99	60
Mar	69.34	44.96	65	59.69	86
Apr	77.72	59.94	77	69.09	89
May	82.04	38.86	47	137.41	167
Jun	86.11	18.54	22	118.87	138
Jul	82.04	98.04	120	75.69*	92*
Aug	79.76	87.38	110	67.56*	85*
Sep	78.49	74.42	95	87.12*	111*
Oct	68.33	106.93	157	54.61*	80*
Nov	70.61	100.84	143	87.88*	124*
Dec	66.04	58.17	88	50.29*	76*
Total	873.51	779.27	89	885.43*	101*

(Continued on next page)

Table 2 (Continued)

Ontario Basin

	Average	1988	% of Average	1989	% of Average
Jan	67.56	41.15	61	45.47	67
Feb	60.20	78.49	130	41.91	70
Mar	67.06	41.40	62	67.06	100
Apr	70.87	69.09	97	46.99	66
May	76.20	55.12	72	119.89	157
Jun	77.98	40.64	52	117.86	151
Jul	78.49	86.36	110	37.34*	48*
Aug	77.98	87.63	112	59.44*	76*
Sep	79.76	66.04	83	95.50*	120*
Oct	75.44	109.73	145	100.58*	133*
Nov	76.71	84.58	110	102.11*	133*
Dec	72.90	51.31	70	44.20*	61*
Total	881.14	811.54	92	878.35*	100*

Great Lakes Basin

	Average	1988	% of Average	1989	% of Average
Jan	53.85	48.26	90	49.02	91
Feb	44.70	48.77	109	32.00	72
Mar	55.12	52.58	95	57.91	105
Apr	63.50	57.40	90	42.42	67
May	74.42	44.20	59	95.76	129
Jun	81.28	38.10	47	98.55	121
Jul	77.72	75.69	97	43.69*	56*
Aug	79.25	122.17	154	72.64*	92*
Sep	85.60	86.61	101	62.74*	73*
Oct	69.85	106.43	152	66.55*	95*
Nov	68.58	111.00	162	81.28*	119*
Dec	58.42	57.40	98	45.72*	78*
Total	812.28	848.61	104	748.28*	92*

Source: NOAA, Corps of Engineers
* Preliminary Data.
Average are for the Period 1900-1988

Table 3 Runoff Conditions in the Canadian Portion of the Basin in 1988 and 1989
(As A Percentage of the Average for Period 1960-1987)

	1988						1989					
	Sup	Hur	S.C.	Eri	Ont	Total	Sup	Hur	S.C.	Eri	Ont	Total
Jan	82	92	60	125	79	86	129	131	89	125	61	118
Feb	83	93	84	122	89	89	140	106	44	56	53	106
Mar	76	85	69	104	69	80	121	90	39	82	48	87
Apr	55	128	46	60	84	92	114	85	66	48	77	86
May	64	94	53	61	71	78	135	90	55	65	112	107
Jun	52	58	32	52	36	53	132	147	149	162	182	143
Jul	43	44	54	76	37	44	131	91	67	75	61	111
Aug	70	81	60	77	40	72	97	66	44	68	67	84
Sep	90	91	44	63	47	84	102	61	39	51	71	83
Oct	132	123	109	81	63	120	89	45	38	58	89	71
Nov	111	210	149	148	88	151	88	69	61	109	151	88
Dec	125	134	59	63	47	111	88	74	24	88	82	78
Total	88	108	68	86	70	92	115	90	54	77	85	97

Source: Water Resources Branch, Environment Canada

Table 4 Evaporation (mm) from the Great Lakes in 1988 & 1989

	Lake Superior			Lake Huron		
	Average	1988	1989	Average	1988	1989
Jan	115.5	119.9	88.6	89.4	105.1	82.7
Feb	40.3	67.0	88.2	37.1	63.2	66.9
Mar	34.6	43.2	25.5	26.9	30.2	30.4
Apr	14.5	14.6	20.4	7.0	5.8	12.0
May	1.6	2.1	1.3	-0.7	1.6	-0.6
Jun	-6.6	-2.7	-6.0	-3.5	5.8	-3.8
Jul	-7.1	-2.5	-4.4	13.3	16.8	13.9
Aug	4.3	-3.0	-4.3	43.7	59.9	52.7
Sep	38.7	29.5	28.7	61.5	70.8	79.4
Oct	60.4	83.8	50.0	77.4	100.7	43.9
Nov	100.1	66.8	134.8	84.3	63.0	132.6
Dec	134.2	146.3		106.0	115.3	
Total	530.5	565.0		542.4	638.2	

	Georgian Bay			Lake Michigan		
	Average	1988	1989	Average	1988	1989
Jan	64.7	111.5	74.8	n/a	123.1	69.1
Feb	19.5	32.3	39.8	n/a	90.6	89.9
Mar	22.6	25.8	18.8	n/a	22.1	31.4
Apr	7.9	5.0	10.0	n/a	7.6	6.3
May	-0.3	1.2	-2.5	n/a	1.9	2.2
Jun	-3.3	7.4	-2.3	n/a	11.9	-0.5
Jul	17.8	19.3	18.2	n/a	29.4	32.7
Aug	49.0	59.6	45.3	n/a	50.3	69.2
Sep	68.5	63.1	76.6	n/a	62.1	122.6
Oct	82.1	98.4	40.7	n/a	139.9	76.7
Nov	91.1	65.9	148.6	n/a	65.6	154.1
Dec	108.0	121.8		n/a	127.9	
Total	527.6	611.3		n/a	732.4	

	Lake Erie			Lake Ontario		
	Average	1988	1989	Average	1988	1989
Jan	40.9	70.7	37.9	96.8	84.0	85.3
Feb	18.8	23.7	26.2	54.7	67.1	71.9
Mar	18.8	17.4	15.2	31.1	29.4	34.7
Apr	8.3	11.3	11.7	7.0	3.1	10.6
May	8.8	16.4	8.5	-1.2	-0.1	-6.1
Jun	30.3	54.1	13.9	0	25.6	-5.4
Jul	73.4	61.4	59.9	27.7	21.2	25.8
Aug	111.0	176.9	142.1	58.7	72.3	77.7
Sep	128.3	138.4	127.0	71.4	73.1	77.3
Oct	122.7	177.8	93.3	73.3	87.1	48.7
Nov	93.0	92.5	157.3	65.8	45.1	113.6
Dec	88.0	103.5		93.6	113.6	
Total	742.3	944.1		578.9	537.5	

Source: Atmospheric Environment Service, Environment Canada.
Average for the period 1965-1988. Negative denotes condensation.

Table 5 Outflows from the Great Lakes in 1988 and 1989
(cubic metres per second)

Lake Superior	1988	1989	Average 1900-1988	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	1780	2240	1930	2630 (1971)	1250 (1922)
Feb	1780	2270	1900	2610 (1969)	1270 (1982)
Mar	1780	2180	1870	2690 (1969)	1270 (1982)
Apr	1780	2210	1950	2940 (1951)	1300 (1982)
May	1980	2630	2120	3450 (1951)	1250 (1931)
Jun	1930	2660	2210	3480 (1951)	1220 (1922)
Jul	1590	2660	2290	3570 (1938)	1270 (1922)
Aug	1590	2610	2380	3600 (1950)	1270 (1926)
Sep	1980	2410	2380	3570 (1950)	1160 (1955)
Oct	1900	2040*	2320	3510 (1968)	1250 (1926)
Nov	1590	1900*	2270	3740 (1985)	1250 (1981)
Dec	2270	1900*	2070	3200 (1950)	1300 (1981)
Annual	1840	2320*	2150		

Lakes Michigan-Huron	1988	1989	Average 1900-1988	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	5150	5150	4450	5920 (1953)	3060 (1934)
Feb	5070	4900	4360	5720 (1974)	3000 (1942)
Mar	5350	4980	4810	5830 (1986)	3510 (1931)
Apr	5610	5240	5150	6260 (1986)	3600 (1901)
May	5640	5320	5350	6370 (1986)	4390 (1964)
Jun	5640	5300	5470	6430 (1985)	4420 (1964)
Jly	5550	5350	5520	6570 (1974)	4500 (1964)
Aug	5490	5350	5520	6630 (1986)	4530 (1964)
Sep	5410	5320	5490	6600 (1986)	4470 (1933)
Oct	5320	5180*	5440	6740 (1986)	4420 (1933)
Nov	5210	5100*	5380	6650 (1986)	4390 (1934)
Dec	5350	5130*	5180	6230 (1986)	3990 (1935)
Annual	5410	5180*	5180		

(Continued on next page)

Table 5 (Continued)

Lake Erie				Previous Recorded Maxima & Minima (Year of Occurrence)	
	1988	1989	Average 1900-1988	Maximum	Minimum
Jan	6340	5890	5550	7420 (1987)	4050 (1936)
Feb	6290	5660	5410	7050 (1987)	3340 (1936)
Mar	6260	5490	5580	7480 (1986)	4110 (1934)
Apr	6340	6120	5860	7700 (1974)	4390 (1935)
May	6480	6310	6170	7760 (1974)	4590 (1934)
Jun	6290	6600	6200	7820 (1986)	4560 (1934)
Jly	6000	6370	6090	7670 (1986)	4450 (1934)
Aug	6090	6310	6000	7420 (1986)	4470 (1934)
Sep	5860	6090	5890	7140 (1986)	4450 (1934)
Oct	5860	5900*	5780	7450 (1986)	4420 (1934)
Nov	5860	5850*	5780	7280 (1986)	4280 (1934)
Dec	5860	5910*	5780	7620 (1985)	4330 (1934)
Annual	6130	6040*	5830		

Lake Ontario				Previous Recorded Maxima & Minima (Year of Occurrence)	
	1988	1989	Average 1961-1987	Maximum	Minimum
Jan	6740	6060	6260	7360 (1955)	4700 (1935)
Feb	7140	6400	6290	8160 (1986)	4360 (1936)
Mar	7360	6200	6600	8550 (1974)	5010 (1935)
Apr	7160	5800	7050	9200 (1973)	5070 (1964)
May	6740	6460	7310	9540 (1973)	4980 (1965)
Jun	7110	7360	7390	9910 (1973)	5350 (1965)
Jly	6880	7960	7330	9910 (1976)	5520 (1934)
Aug	6970	7650	7160	9340 (1974)	5300 (1934)
Sep	6880	7420	6990	9230 (1986)	5100 (1934)
Oct	6770	7220	6800	9170 (1986)	4960 (1934)
Nov	6990	7420	6680	9570 (1986)	4810 (1934)
Dec	6970	6740	6570	9260 (1986)	4810 (1934)
Annual	6970	6880	6870		

Source: Water Planning and Management Branch, Environment Canada

Table 6 Great Lakes Water Levels in 1988 and 1989 and Their Comparison with Previous Records (Metres, IGLD-1955)

Lake Superior at Thunder Bay			Average	Previous Recorded Maxima & Minima (Year of Occurrence)	
	1988	1989	1916-1987	Maximum	Minimum
Jan	182.88	183.03	183.01	183.33 (1986)	182.49 (1926)
Feb	182.82	182.93	182.95	183.27 (1986)	182.44 (1926)
Mar	182.78	182.89	182.92	183.25 (1986)	182.41 (1926)
Apr	182.81	182.92	182.95	183.31 (1986)	182.39 (1926)
May	182.85	183.00	183.06	183.38 (1986)	182.43 (1926)
Jun	182.88	183.12	183.15	183.46 (1916)	182.53 (1926)
Jul	182.89	183.15	183.22	183.55 (1916)	182.64 (1926)
Aug	183.00	183.13	183.24	183.54 (1916)	182.70 (1926)
Sep	183.05	183.11	183.24	183.56 (1916)	182.78 (1926)
Oct	183.01	183.01	183.21	183.55 (1985)	182.77 (1925)
Nov	183.07	182.97	183.15	183.52 (1985)	182.67 (1925)
Dec	183.06	182.89*	183.08	183.42 (1985)	182.58 (1925)

Lake Huron at Goderich			Average	Previous Recorded Maxima & Minima (Year of Occurrence)	
	1988	1989	1916-1987	Maximum	Minimum
Jan	176.45	176.17	176.13	176.98 (1987)	175.40 (1965)
Feb	176.44	176.15	176.10	176.90 (1986)	175.40 (1964)
Mar	176.37	176.11	176.11	176.92 (1986)	175.37 (1964)
Apr	176.48	176.20	176.19	177.02 (1986)	175.37 (1964)
May	176.50	176.24	176.28	177.07 (1986)	175.51 (1964)
Jun	176.48	176.35	176.37	177.12 (1986)	175.53 (1964)
Jul	176.43	176.36	176.41	177.17 (1986)	175.55 (1964)
Aug	176.39	176.34	176.40	177.20 (1986)	175.56 (1964)
Sep	176.30	176.28	176.35	177.17 (1986)	175.56 (1964)
Oct	176.25	176.14	176.28	177.28 (1986)	175.51 (1964)
Nov	176.20	176.12	176.23	177.19 (1986)	175.46 (1964)
Dec	176.24	175.99*	176.19	177.07 (1986)	175.40 (1964)

Lake St. Clair at Belle River			Average	Previous Recorded Maxima & Minima (Year of Occurrence)	
	1988	1989	1961-1987	Maximum	Minimum
Jan	175.11	174.81	174.92	175.62 (1986)	173.97 (1964)
Feb	175.06	174.83	174.88	175.63 (1986)	173.97 (1964)
Mar	175.04	174.75	175.01	175.64 (1986)	174.15 (1964)
Apr	175.12	174.89	175.09	175.65 (1986)	174.27 (1964)
May	175.12	174.94	175.15	175.67 (1986)	174.37 (1964)
Jun	175.08	175.11	175.19	175.75 (1986)	174.35 (1964)
Jul	175.03	175.13	175.19	175.76 (1986)	174.34 (1964)
Aug	174.98	175.04	175.16	175.73 (1986)	174.33 (1964)
Sep	174.88	174.99	175.10	175.67 (1986)	174.26 (1964)
Oct	174.79	174.83	175.02	175.79 (1986)	174.15 (1964)
Nov	174.77	174.72	174.95	175.65 (1986)	174.07 (1964)
Dec	174.77	174.66*	174.97	175.62 (1986)	174.07 (1964)

(Continued on next page)

Table 6 (Continued)

Lake Erie at Port Colborne	1988	1989	Average 1916-1987	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	174.24	173.94	173.81	174.71 (1987)	173.08 (1935)
Feb	174.19	173.94	173.75	174.55 (1987)	173.00 (1935)
Mar	174.17	173.84	173.82	174.70 (1986)	173.00 (1934)
Apr	174.28	174.06	173.97	174.81 (1985)	173.18 (1935)
May	174.24	174.12	174.06	174.76 (1986)	173.24 (1934)
Jun	174.20	174.32	174.10	174.84 (1986)	173.24 (1934)
Jul	174.14	174.29	174.09	174.83 (1986)	173.23 (1934)
Aug	174.09	174.20	174.03	174.75 (1986)	173.21 (1934)
Sep	173.96	174.08	173.94	174.63 (1986)	173.18 (1934)
Oct	173.95	173.98	173.87	174.75 (1986)	173.15 (1934)
Nov	173.93	174.02	173.84	174.68 (1986)	173.06 (1934)
Dec	173.93	173.85*	173.84	174.75 (1986)	173.09 (1934)

Lake Ontario at Kingston	1988	1989	Average 1916-1987	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	74.37	74.26	74.39	75.02 (1946)	73.66 (1965)
Feb	74.42	74.25	74.41	75.11 (1952)	73.64 (1936)
Mar	74.41	74.20	74.50	75.22 (1952)	73.80 (1935)
Apr	74.56	74.52	74.70	75.47 (1952)	73.89 (1935)
May	74.70	74.80	74.83	75.57 (1952)	73.98 (1935)
Jun	74.74	75.03	74.88	75.61 (1952)	73.95 (1935)
Jul	74.69	75.01	74.84	75.51 (1947)	74.00 (1934)
Aug	74.64	74.84	74.73	75.44 (1947)	73.86 (1934)
Sep	74.51	74.66	74.59	75.27 (1947)	73.77 (1934)
Oct	74.40	74.51	74.47	75.09 (1945)	73.69 (1934)
Nov	74.37	74.49	74.39	75.04 (1945)	73.61 (1934)
Dec	74.29	74.38*	74.38	75.06 (1945)	73.60 (1934)

Montreal Harbour (Jetty No.1)	1988	1989	Average 1967-1987	Previous Recorded Maxima & Minima (Year of Occurrence) Maximum	Minimum
Jan	6.27R	6.15R	7.02	8.91 (1968)	6.38 (1972)
Feb	6.52	6.28R	7.15	8.99 (1967)	6.33 (1977)
Mar	6.22R	6.07R	7.19	8.31 (1973)	6.49 (1970)
Apr	7.13R	6.38R	7.70	8.77 (1976)	7.16 (1970)
May	6.49	6.54	7.51	8.89 (1974)	6.38 (1968)
Jun	5.87R	6.63	6.91	8.08 (1974)	6.05 (1968)
Jul	5.66R	6.26	6.64	7.45 (1973)	5.90 (1977)
Aug	5.88R	6.05	6.53	7.23 (1972)	5.93 (1967)
Sep	5.87R	5.89	6.48	7.03 (1986)	5.89 (1967)
Oct	6.21	5.87R	6.52	7.11 (1986)	6.08 (1971)
Nov	6.95	6.37	6.60	7.27 (1967)	5.91 (1971)
Dec	6.33	6.50*	6.69	7.20 (1972)	5.82 (1978)

Source: Fisheries and Oceans Canada
R denotes new record. * Preliminary Data.

Table 7 Lakes Superior and Michigan-Huron Supply Summary
(cubic metres per second)

Lake Superior Net Basin Supplies (CMS)

	1900-1988 Average	1988 N.B.S. (cms)	1988 Difference in Storage (m)	1989 N.B.S. (cms)	1989 Difference in Storage (m)
Jan	-400 cms	-680 cms	-0.01 m	540 cms	+0.03 m
Feb	310	-1050	-0.04	-480	-0.03
Mar	1270	1530	+0.01	1610	+0.01
Apr	4220	3090	-0.04	3850	-0.01
May	5240	3600	-0.05	5860	+0.02
Jun	4450	2120	-0.07	5240	+0.03
Jul	3680	1760	-0.06	1900	-0.06
Aug	2860	5970	+0.10	2460	-0.01
Sep	2100	1590	-0.02	-230	-0.07
Oct	1080	910	-0.01	960	0
Nov	540	4920	+0.14	-1080	-0.05
Dec	-650	-570	0	-1100	-0.01
Sum	24700	23190	-0.05	19530	-0.16

Lakes Michigan-Huron Net Basin Supplies (CMS)

	1900-1988 Average	1988 N.B.S. (cms)	1988 Difference in Storage (m)	1989 N.B.S. (cms)	1989 Difference in Storage (m)
Jan	1500 cms	990 cms	-0.01 m	1330 cms	0 m
Feb	2520	1840	-0.02	-170	-0.06
Mar	5210	4020	-0.03	5860	+0.01
Apr	8130	8810	+0.02	6060	-0.05
May	7110	3450	-0.08	6030	-0.02
Jun	5780	1330	-0.10	6650	+0.02
Jul	3620	1610	-0.04	1160	-0.06
Aug	1560	760	-0.02	540	-0.02
Sep	910	540	-0.01	-2150	-0.07
Oct	30	480	+0.01	-420	-0.01
Nov	1020	6950	+0.13	820	0
Dec	820	710	0	-1300	-0.05
Sum	38210	31490	-0.15	24410	-0.31

Source: International Lake Superior Board of Control
31360 cms-month is equivalent to 1 metre storage on Lake Superior
44690 cms-month is equivalent to 1 metre storage on Lakes Mich-Huron

Table 8 Lake Ontario Supply Summary

	1900-1988 Average	1988 N.B.S. (cms)	1988 Difference in Storage (metres)	1989 N.B.S. (CMS)	1989 Difference in Storage (metres)
Jan	910 cms	480 cms	-0.06 m	400 cms	-0.07 m
Feb	1050	1160	+0.01	280	-0.10
Mar	2120	1470	-0.09	1440	-0.09
Apr	2630	2040	-0.08	2040	-0.08
May	1700	1220	-0.06	2490	+0.11
Jun	1160	450	-0.10	1980	+0.11
Jul	680	590	-0.01	110	-0.08
Aug	230	0	-0.03	80	-0.02
Sep	140	0	-0.02	200	+0.01
Oct	200	310	+0.01	420	+0.03
Nov	570	1130	+0.11	1250	+0.09
Dec	760	310	-0.06	80	-0.09
Sum	12150	9160	-0.40	10770	-0.19

Source: International St. Lawrence River Board of Control
7430 cms-months is equivalent to 1 metre storage on Lake Ontario

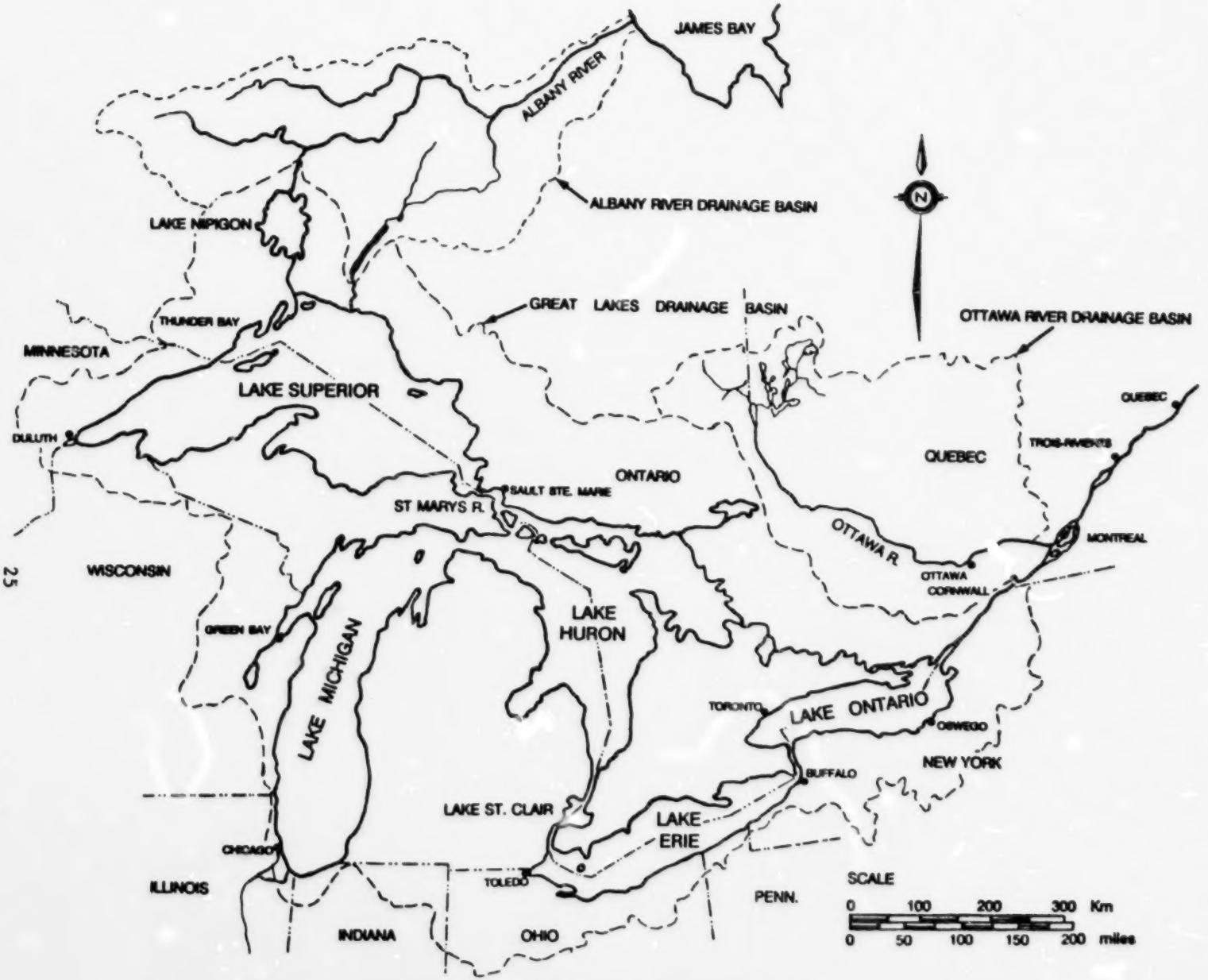

Figure 1 GREAT LAKES - ST. LAWRENCE RIVER BASIN

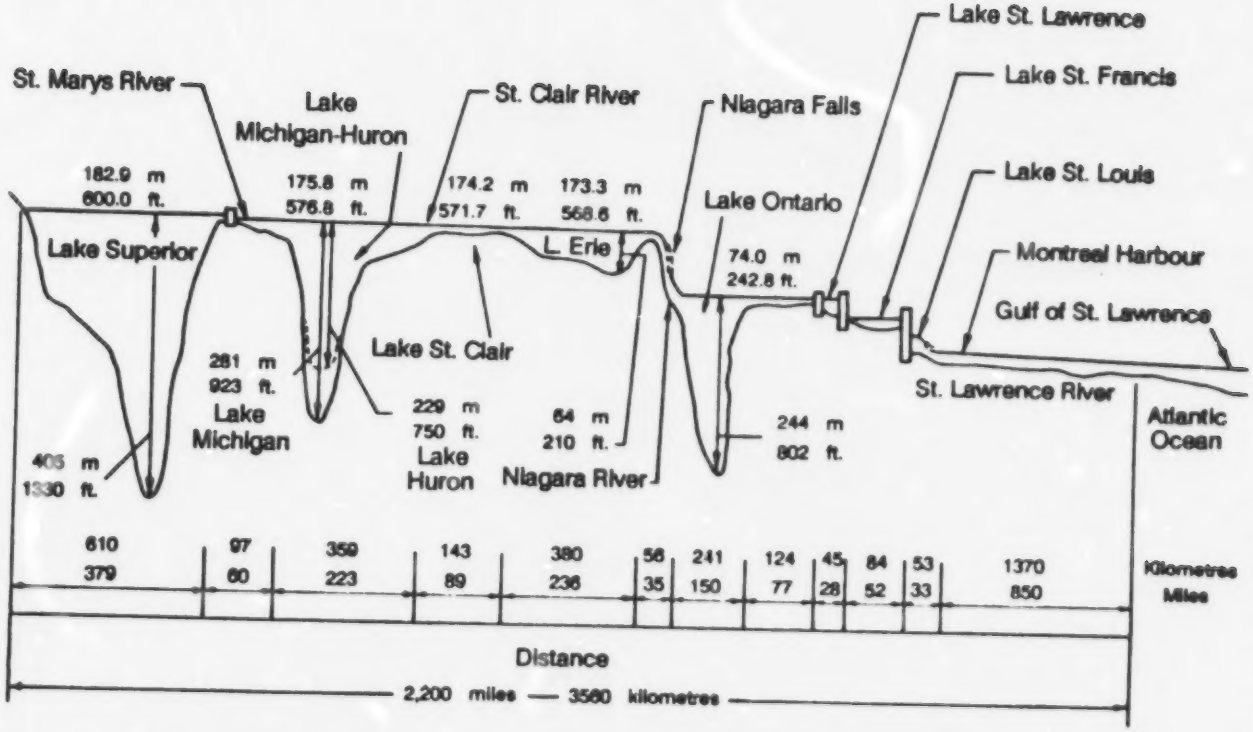

Figure 2 SCHEMATIC PROFILE OF THE GREAT LAKES - ST. LAWRENCE RIVER SYSTEM

LAKE SUPERIOR (Thunder Bay) LAC SUPÉRIEUR

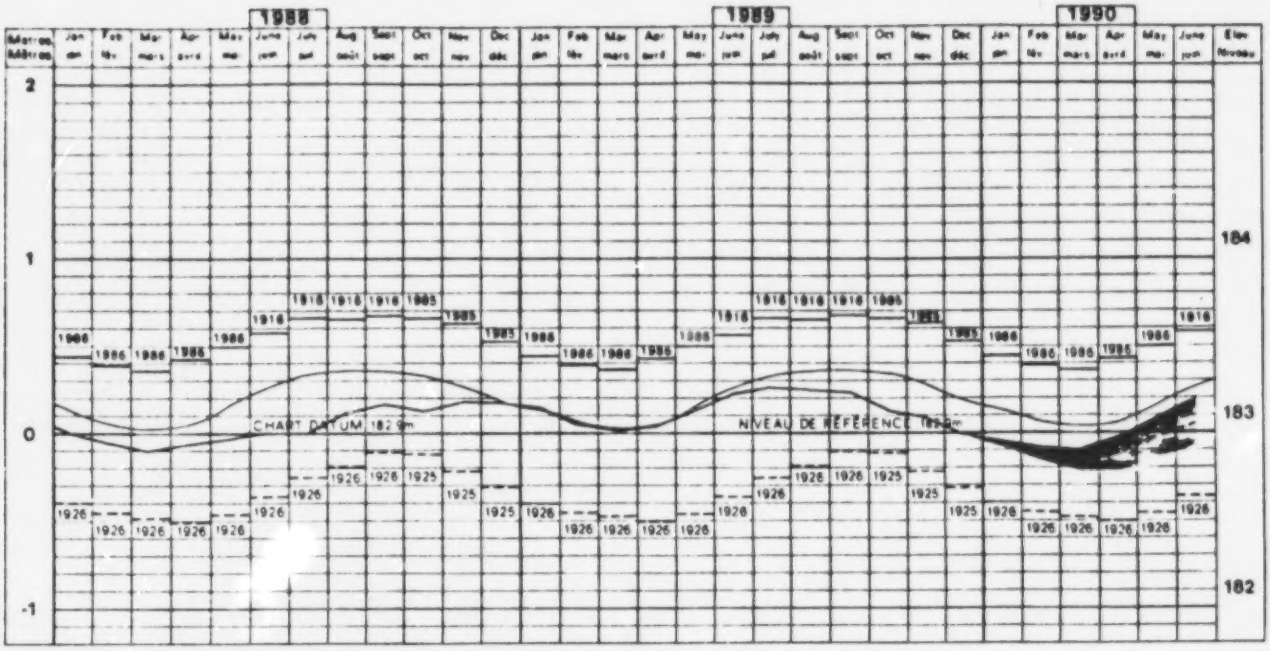

Figure 3 WATER LEVEL HYDROGRAPH OF LAKE SUPERIOR

LAKE HURON (Goderich) LAC HURON

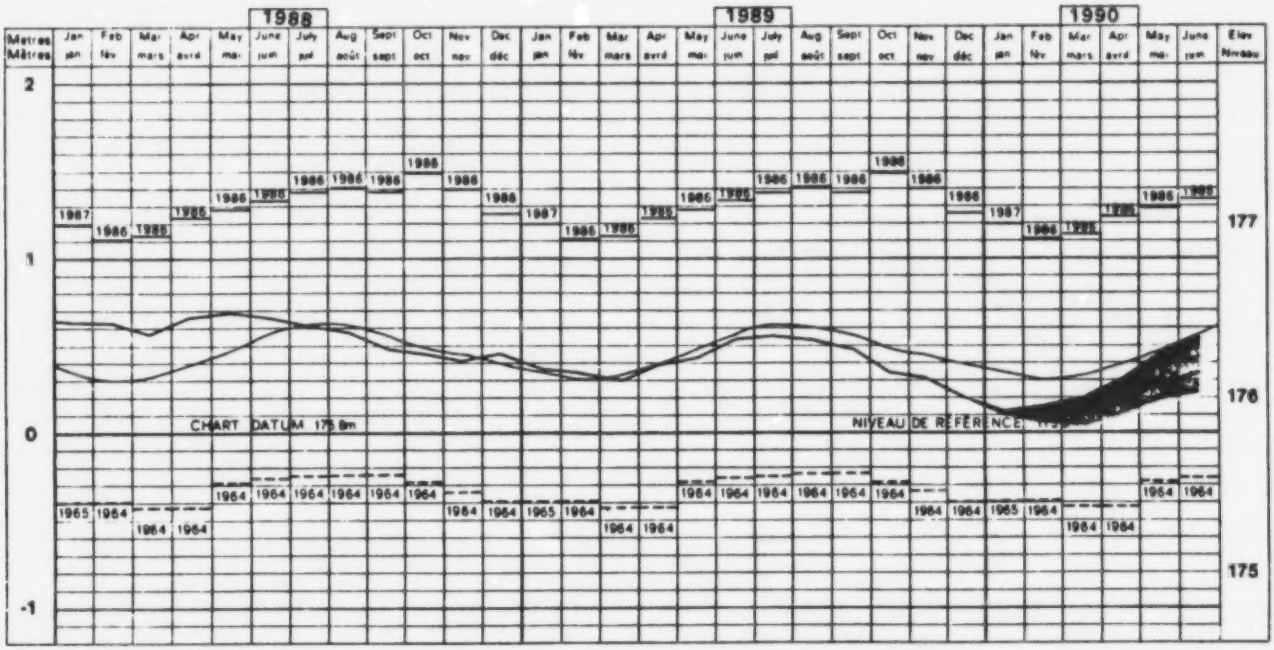

Figure 4 WATER LEVEL HYDROGRAPH OF LAKES MICHIGAN-HURON

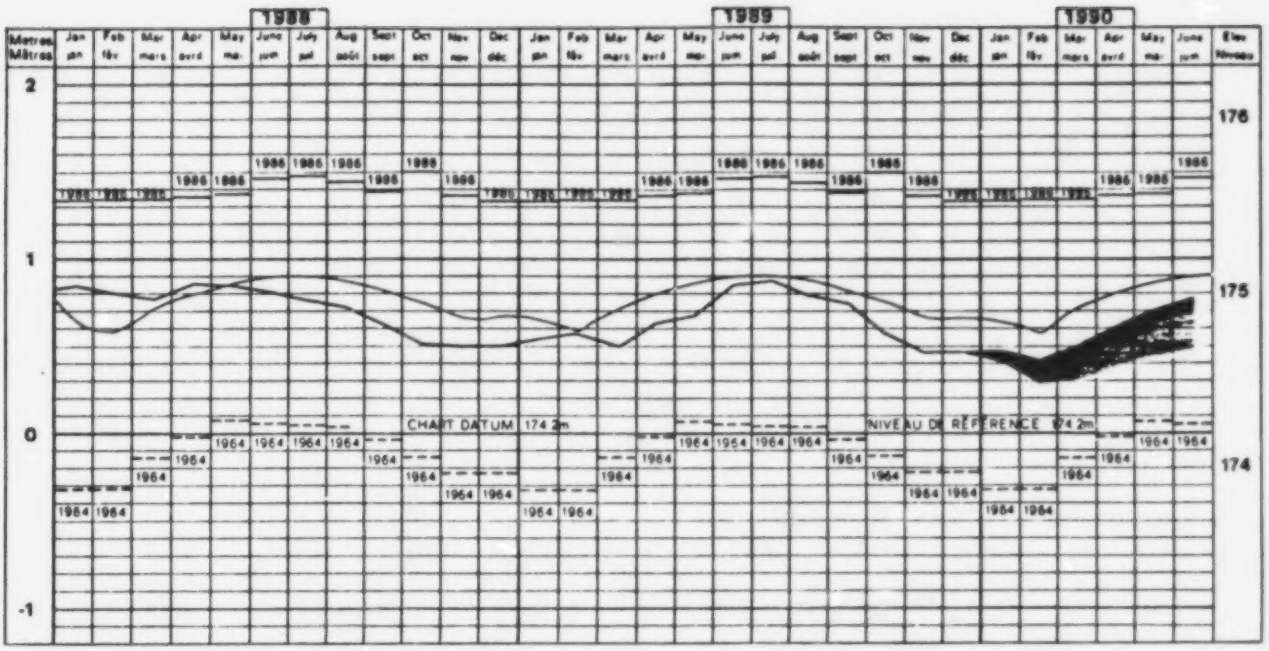

Figure 5 WATER LEVEL HYDROGRAPH OF LAKE ST. CLAIR

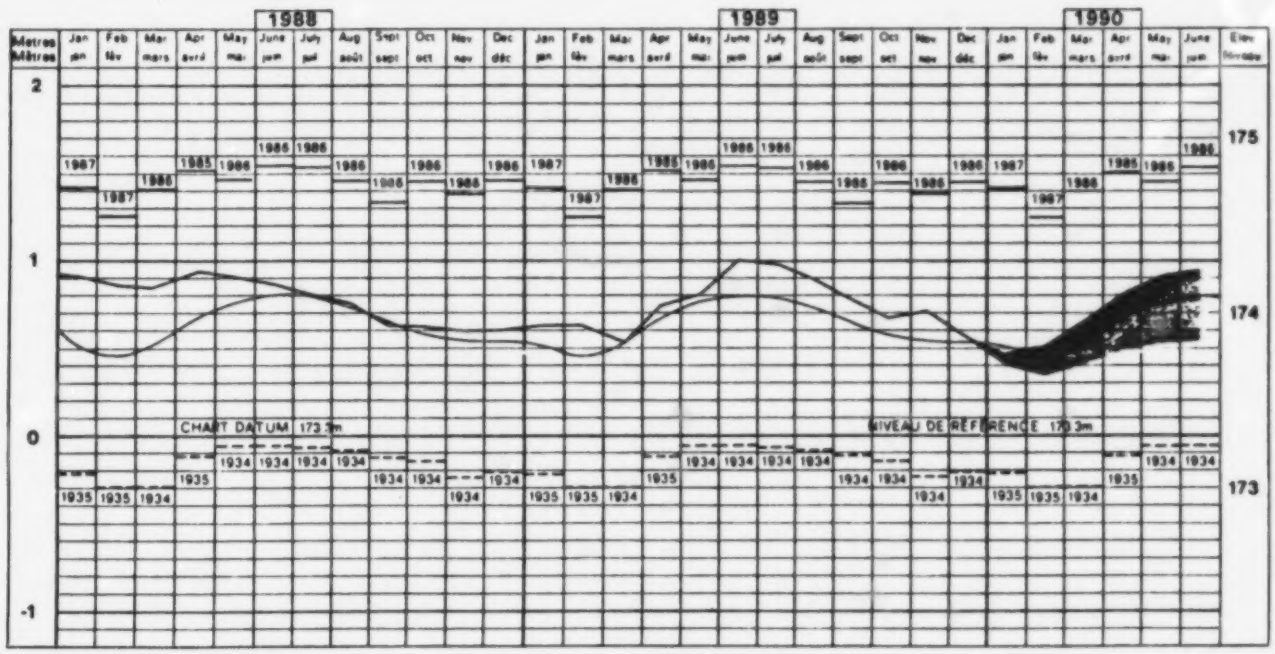

Figure 6 WATER LEVEL HYDROGRAPH OF LAKE ERIE

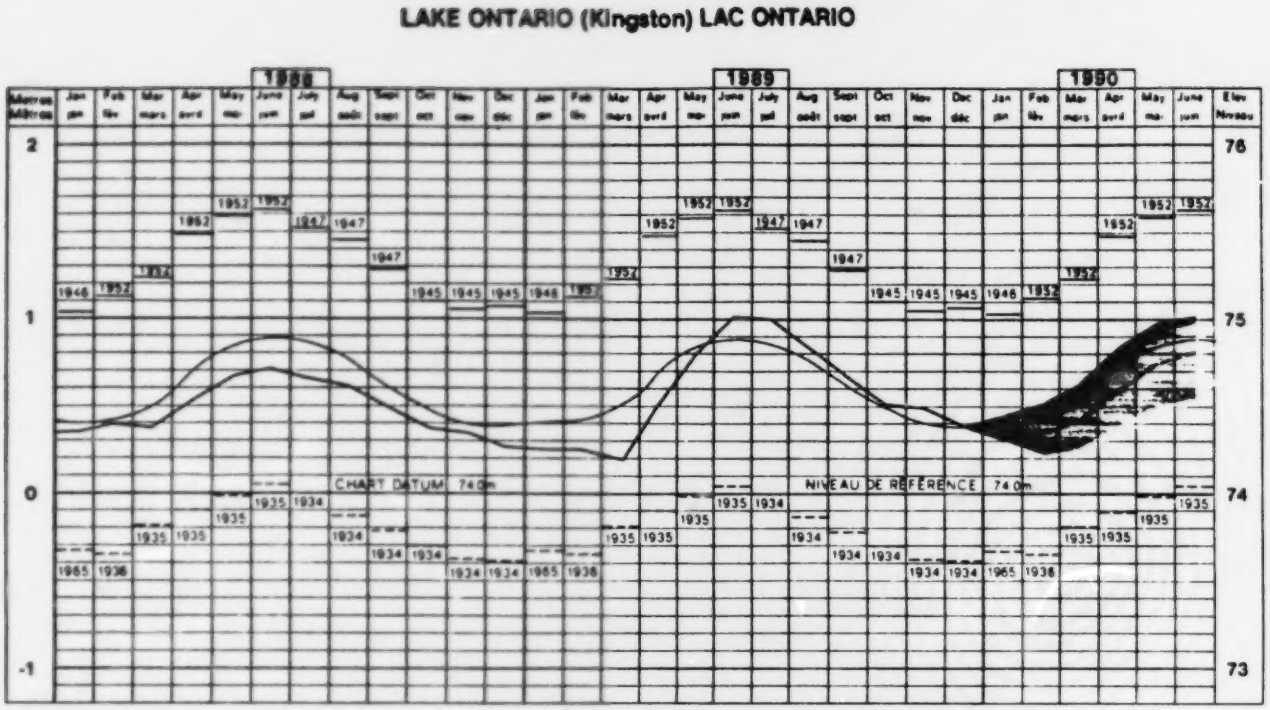

Figure 7 WATER LEVEL HYDROGRAPH OF LAKE ONTARIO

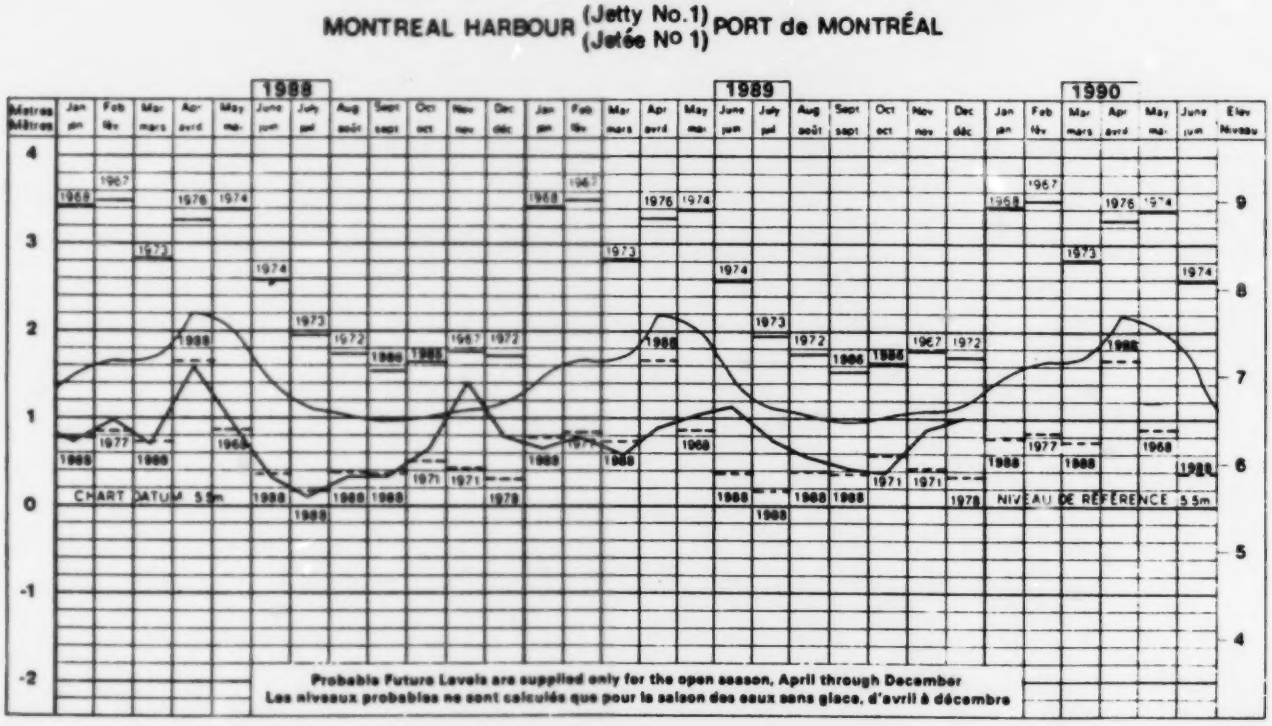
MONTREAL HARBOUR (Jetty No.1) (Jetée No 1) PORT de MONTRÉAL
1988
1989
1990
CHART DATUM 5 5m
NIVEAU DE RÉFÉRENCE 5 5m
Probable Future Levels are supplied only for the open season, April through December
Les niveaux probables ne sont calculés que pour la saison des eaux sans glace, d'avril à décembre

Figure 8 WATER LEVEL HYDROGRAPH OF MONTREAL HARBOUR